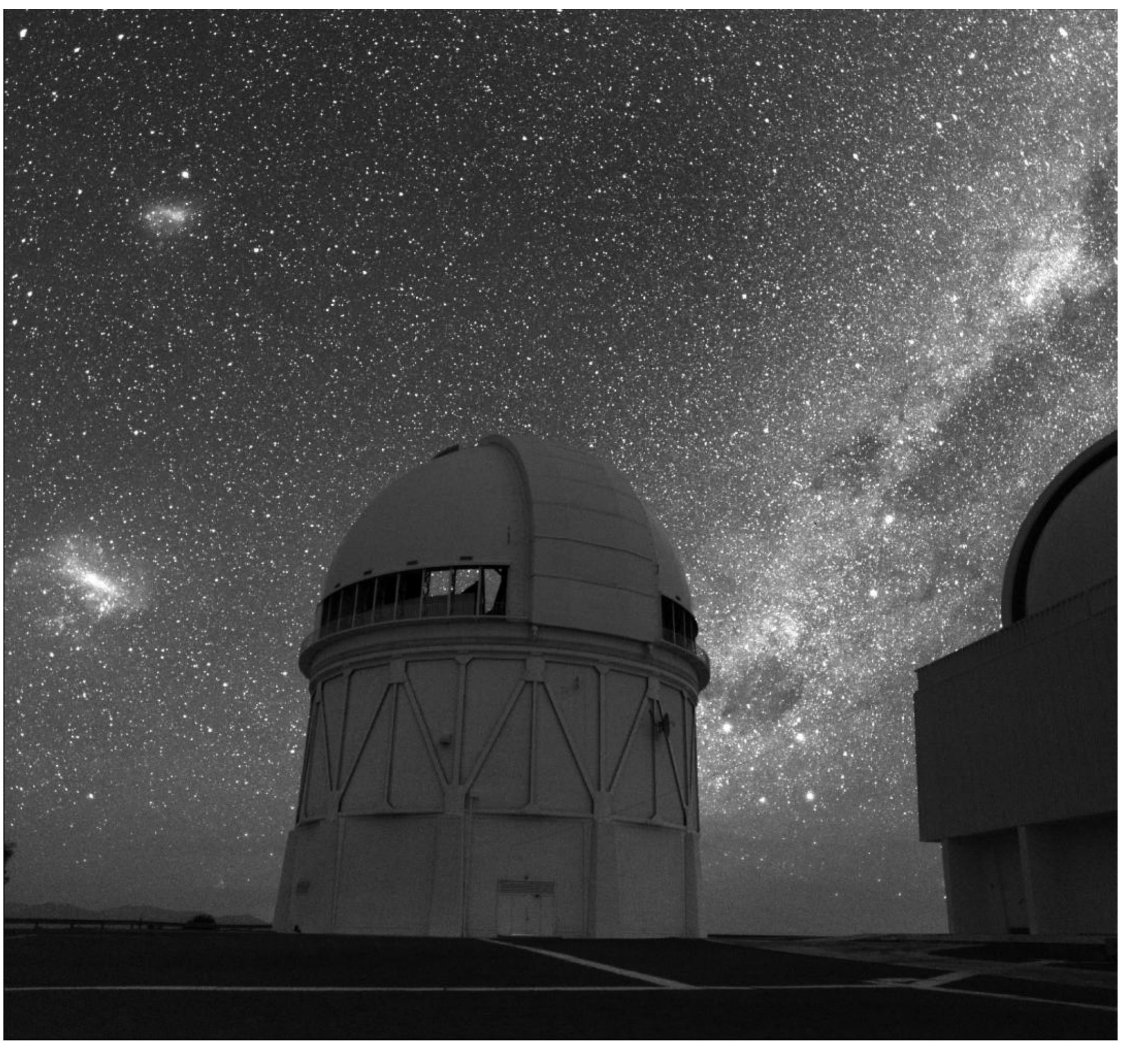
Introduction to telescope observing
or
Observing for those that don't plan on observing

Alex Kim

An opportunity for the audience to gain an appreciation of some of the important elements of data taking, understand some random astronomical jargon and concepts, and data reduction.

Organization:

I will discuss what goes into an observing run at an optical telescope. Certain ideas will be delved into more detail as we go along.



Before you go

Be prepared! Easier to make decisions at home than at the telescope.

IT IS HARD TO THINK AT A TELESCOPE

- 2/3 oxygen at Mauna Kea

Read observer guide - every telescope a different animal

- know how to control telescope, camera

Make a target list

- Positions
- Exposure times and filters/blaze
  - Decide on slit angle
- Finder charts - correct field of view, correct depths, offset stars
- standard stars - for calibration
- observing plan -ephemeris, target information, when to observe what
  - skycalc

Contingency plan - what if there is bad transmission, patchy clouds, or bad seeing?

Know how to look at data at telescope - IRAF, MIDAS, IDL, custom

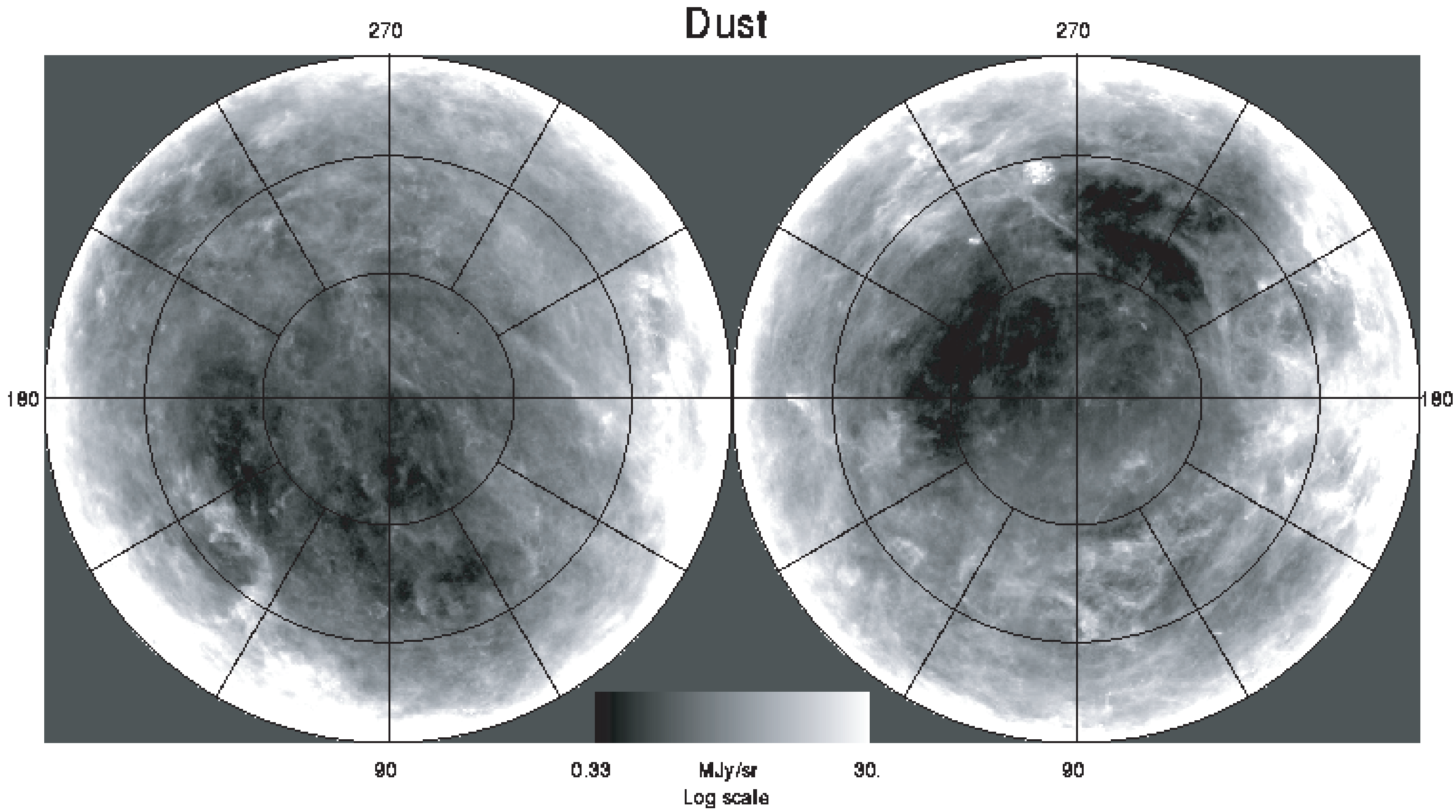
Binocular, telescope, flashlight, warm clothes - yes there are blizzards in Hawaii

Targets

For SN searching the main requirements are:

- High-galactic lattitude
- Visible to north and southern hemisphere: 0 dec
- Visible for several months - don't observe too far low RA for references
- Previously observed fields

Spectroscopic targets from search



Extinction maps have been made from IR emission (Schlegel, Finkbeiner, & Davis 1998) and galaxy counts, HI column densities, and reddening (Burstein & Heiles 1978).

Cardelli, Clayton, & Mathis (1989) made a single parameter model of an average extinction law. There is more absorption at short wavelengths meaning that extincted objects look redder. "Reddening" and "extinction" are synonymous.

Things extinction are parametrized as follows.

$A_V = R_V\, E(B-V)$

A_V : Extinction in the V band

R_V : A parameter determined by the dust model and source.

E(B-V) : Color excess. The expected color - observed color.

$$(B-V)^{True} - (B-V)^{Obs}$$

Typically $R_V=3.1$, $R_B=4.1$ so a color errors propagate into large mag errors.

Note that B&H E(B-V) and CCM R_V have different meanings.

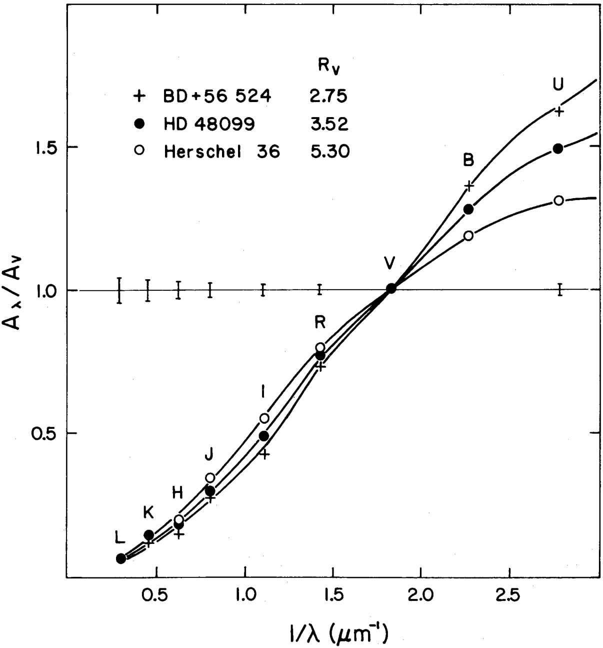
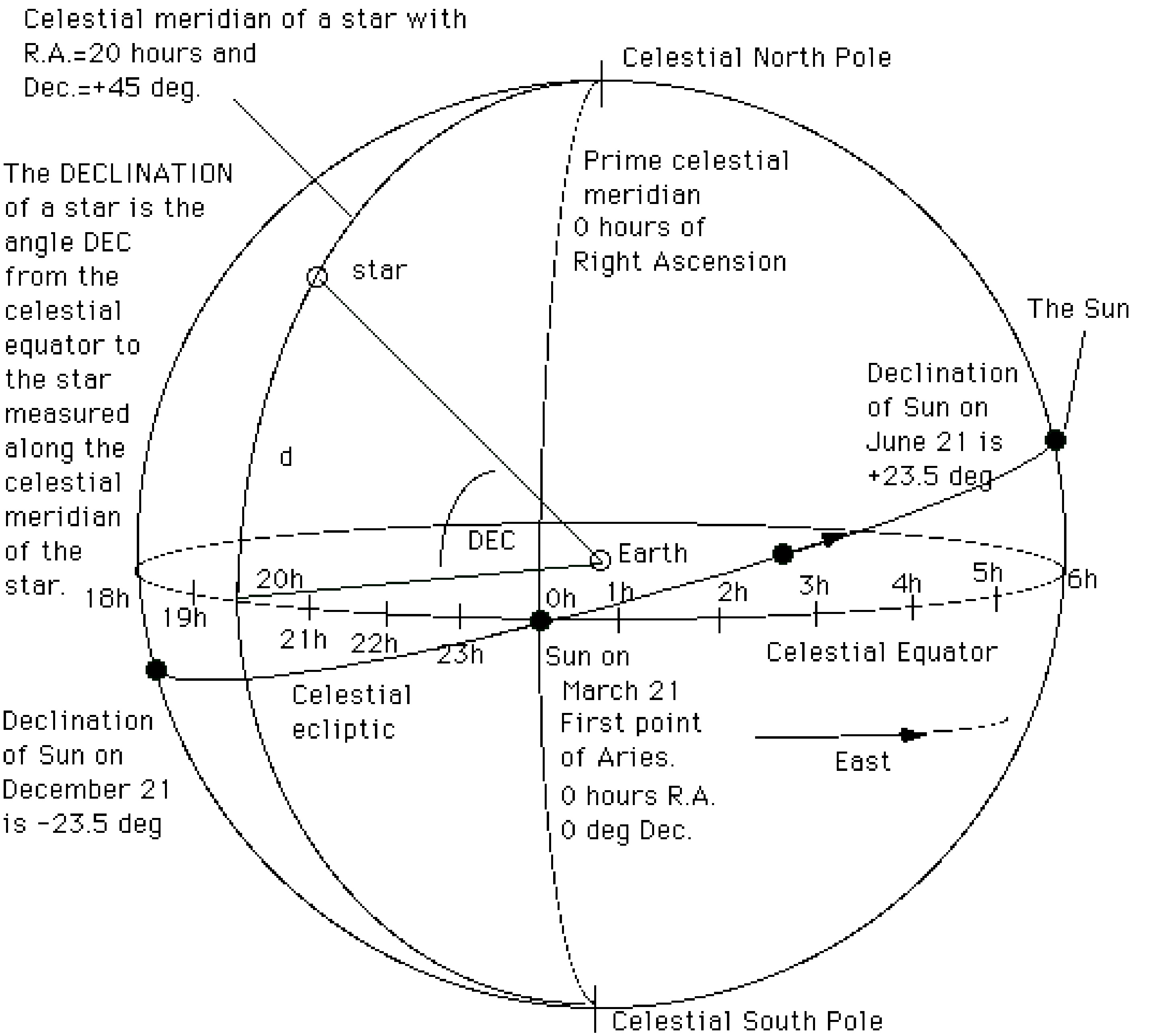


FIG. 3.—Comparison between the mean optical/NIR R_V-dependent extinction law from eqs. (2) and (3) and three lines of sight with largely separated R_V values. The wavelength position of the various broad-band filters from which the data were obtained are labeled (see Table 3). The "error" bars represent the computed standard deviation of the data about the best fit of $A(\lambda)/A(V)$ vs. R_V^{-1} with $a(x) + b(x)/R_V$ where $x \equiv \lambda^{-1}$. The effect of varying R_V on the shape of the extinction curves is quite apparent, particularly at the shorter wavelengths.

CELESTIAL SPHERE, RIGHT ASCENSION (in hours), AND DECLINATION (in deg. + or -)



A Celestial meridian is half a great circle (cuts celestial sphere in half) through the north and south celestial poles, analogous to a meridian on Earth. The celestial equator and ecliptic are great circles that intersect at two points. The intersection near the sun's position on March 21 is called the First Point of Aries, or the Vernal Equinox. Its meridian is the prime meridian, analogous to the Greenwich meridian. The analog of longitude in the celestial sphere is RIGHT ASCENSION. Each 15 degrees along the celestial equator is marked as ONE HOUR OF RIGHT ASCENSION, increasing toward the east. As the Earth rotates toward the east, the celestial sphere seems to move from east to west. This motion brings successive hours of right ascension on to your local meridian. Your local sidereal time is the right ascension of your local meridian.

Position

Due to the precession of the Earth and proper motion, the RA and Dec of a celestial object changes as a function of time. The position of a target is thus given with respect to a fixed system.

In 1976, the International Astronomical Union established the FK5 Fricke system to replace the old IAU 1958 FK4 Bessel-Newcomb system. The FK5 J2000 and FK4 B1950 are frequently used. The transformation between them is non-trivial.

Bottom line: Coordinates should have a specified system.
The telescope is smart enough to precess into current RA, Dec

Time

Universal time : The mean solar time at Greenwich. The same value for all locations. Solar day is the interval between meridian transits of the mean sun.

Local Siderial time : The RA at the observers zenith.

Again the transformation between the two is non-trivial due to the difference between solar and siderial days.

Julian Date : Number of days since 4713 BC Jan 1 from noon Greenwich.
1995 October 9th - JD=2450000

Position redux

Hour angle : RA - LST
Lets you know how long until or since the object crosses you longitude.
When observing you want to minimize the airmass $\chi=\sec(\theta)$, i.e. minimize HA. More airmass decreases atmospheric transmission, increases seeing.

Know where your targets will be

Output from "skycalc"

*** Hourly airmass for blah ***

Epoch 2000.00: RA 4 16 55.3, dec 19 42 09
Epoch 2002.08: RA 4 17 02.6, dec 19 42 27

At midnight: UT date 2002 Jan 30, Moon 0.97 illum, 86 degr from obj
-- CAUTION -- proximity to Saturn -- low-precision calculation shows
this direction as 2.16 deg away from Saturn ---

Local	UT	LMST	HA	secz	par.angl.	SunAlt	MoonAlt
19 00	5 00	3 15	-1 02	1.033	-86.9	-11.6	...
20 00	6 00	4 15	-0 02	1.000	-73.2	...	6.1
21 00	7 00	5 16	0 58	1.030	87.0	...	19.3
22 00	8 00	6 16	1 59	1.131	84.6	...	32.8
23 00	9 00	7 16	2 59	1.344	81.9	...	46.5
0 00	10 00	8 16	3 59	1.784	78.9	...	60.2
1 00	11 00	9 16	4 59	2.883	75.4	...	73.8
2 00	12 00	10 16	5 59	8.540	71.3	...	84.9
3 00	13 00	11 17	6 59	(down)	66.2	...	76.6
4 00	14 00	12 17	8 00	(down)	59.7	...	63.0
5 00	15 00	13 17	9 00	(down)	50.8	...	49.2
6 00	16 00	14 17	10 00	(down)	38.4	-13.9	35.5
7 00	17 00	15 17	11 00	(down)	21.2	-0.3	21.8

Exposure time calculation

SNR = Nt/sqrt(Nt + pSt +pR^2)

where

N=count rate in electrons per second per image.

t=integration time.

R=Read-noise in electrons

p=Number of pixels in stellar image.

S=electrons per second per pixel from sky.

Notice:
N and S depend on the size of the aperture and system throughput

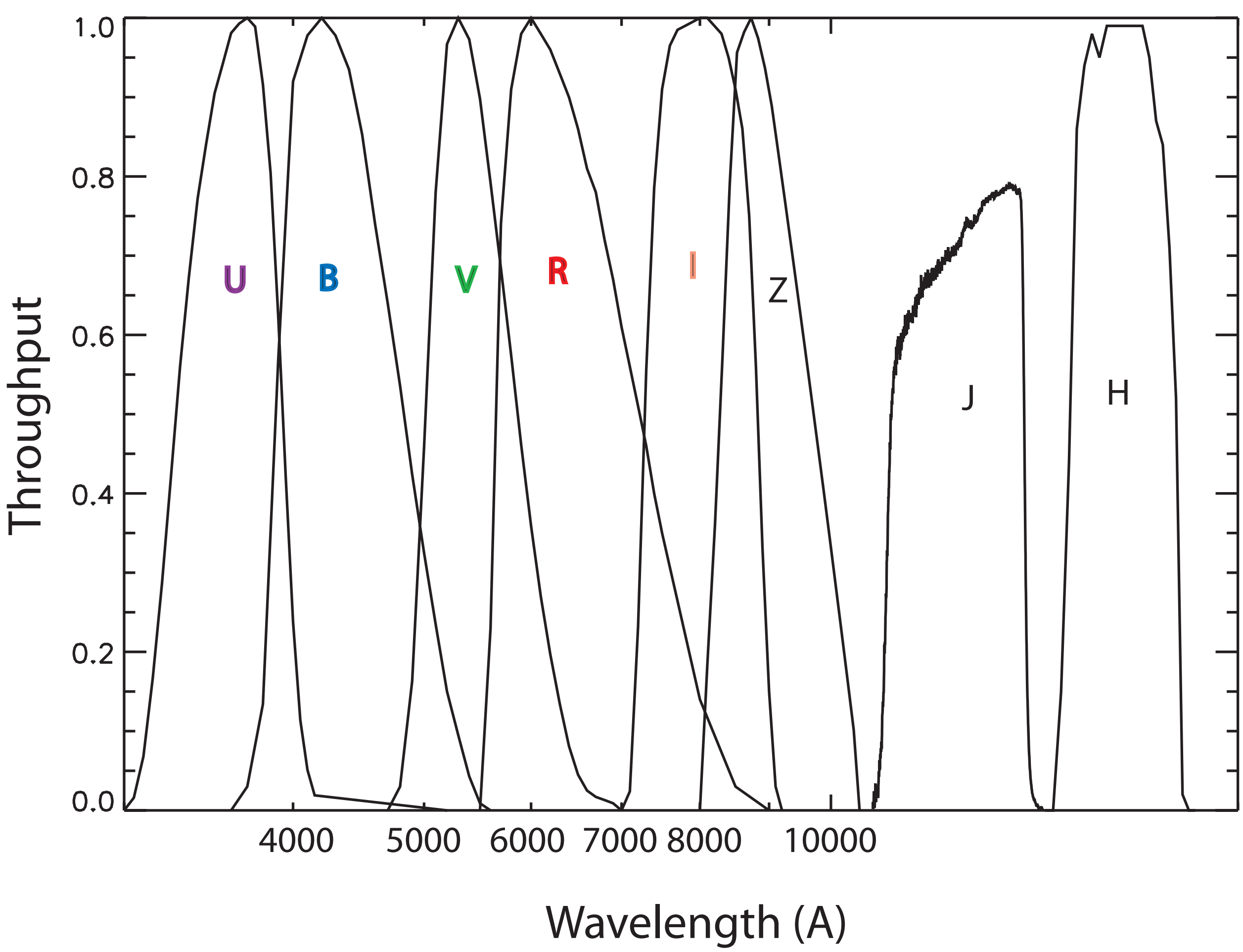
p and S depend on observing conditions
The point-spread-function is described by its FWHM = seeing
The larger the seeing, the more pixels the source falls on

S depends on the moon.

Sky brightness (mag/$arcsec^2$)

lunar age (days)	U	B	V	R	I
0	22.0	22.7	21.8	20.9	19.9
3	21.5	22.4	21.7	20.8	19.9
7	19.9	21.6	21.4	20.6	19.7
10	18.5	20.7	20.7	20.3	19.5
14	17.0	19.5	20.0	19.9	19.2

Observe blue when there is no moon. IR instruments on during full moon.



1.0
0.8
0.6
0.4
0.2
0.0
Throughput
U
B
V
R
I
Z
J
H
4000
5000
6000
7000
8000
10000
Wavelength (A)

Standard stars

Definition of magnitude

$m=-2.5 \log_{10} (\text{flux}) + \text{zeropoint}$
or equivalently
$m=\log_{0.398...}(\text{flux}) + \text{zeropoint}$

Standard stars "define" the magnitude system through the zeropoints.

The Johnson-Cousins magnitude system is a photon flux system defined by tens of primary standards.

Primary standards are very bright and not always accessible. Secondary standards (Landolt) are used.

There is no Hz^{-1} in the zeropoint. The magnitudes are defined based on the integrated flux over the broad passbands that Johnson and Cousins happened to use.

Use standard stars of different colors to produce a "photometric solution" that transform between instrumental and J-C passbands.

$b=-2.5 \log (b \text{ counts/sec})$
$v=-2.5 \log (v \text{ counts/sec})$

$m_B= b + a_0 + a_1 (b-v) + a_2 \chi + O^2 (b,b-v,\chi) + f(t)$

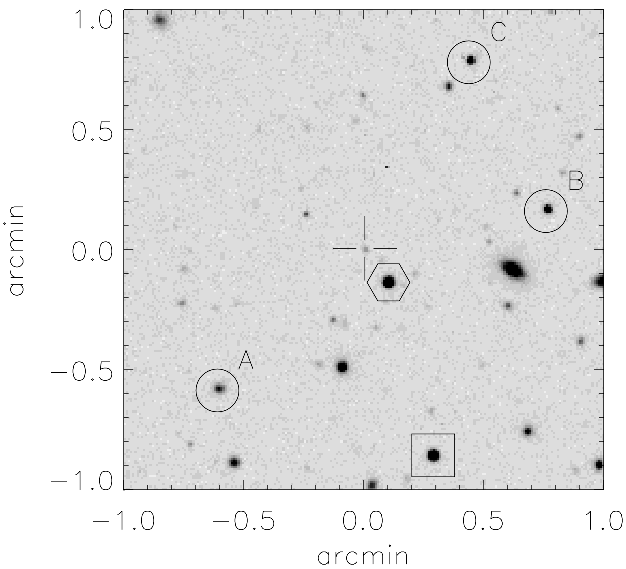
$a_1 (b-v)$ is sometimes called the "color correction"
To do this well you need to observe standards with a range of color and airmass over the night.

AB Magnitude

AB Mag=$-2.5 \log (\text{flux}) -48.6$
where the flux has units erg/s/cm/Hz

Finding chart for S01−023

aka Purcell



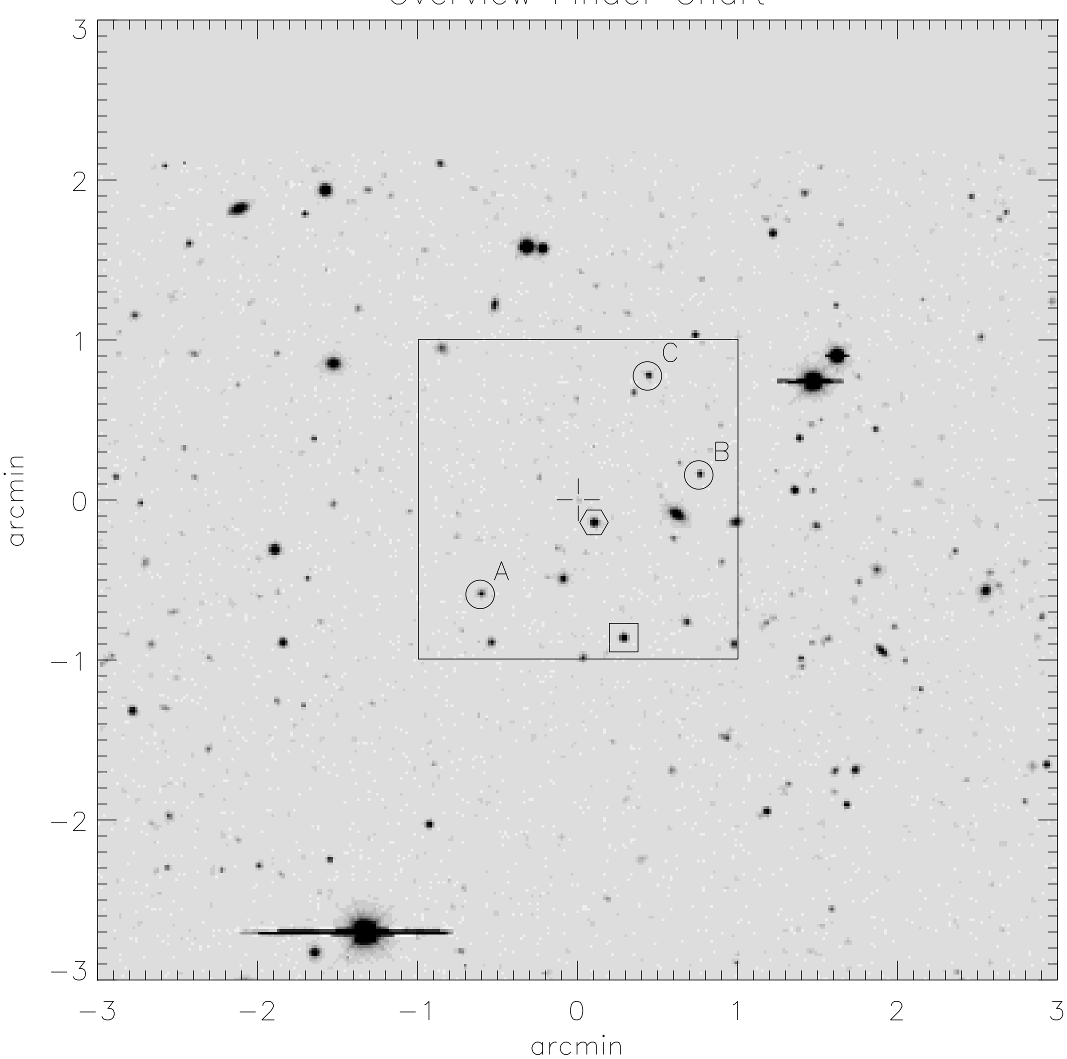
CANDIDATE (cross):
RA(1950): 9 h 57 m 52.01 s
Dec(1950): + 6 d 3' 44.0''

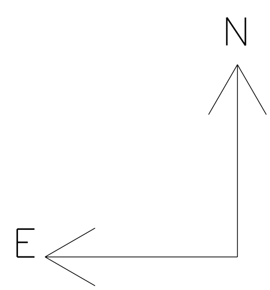
RA(2000): 10:00:29.23
Dec(2000): +05:49:17.82

HEX Star: Mag: 18.04
RA(1950): 9 h 57 m 51.60 s
Dec(1950): + 6 d 3' 35.9''
Offset (E,N,1950) to cand: 6.03'', 8.14''
6.03'' east, 8.14'' north

BOX Star: Mag: 18.29
RA(1950): 9 h 57 m 50.85 s
Dec(1950): + 6 d 2' 52.5''
Offset (E,N,1950) to cand: 17.24'', 51.46''
17.24'' east, 51.46'' north
Offset (E,N,1950) to hex: 11.20'', 43.32''

Overview Finder Chart





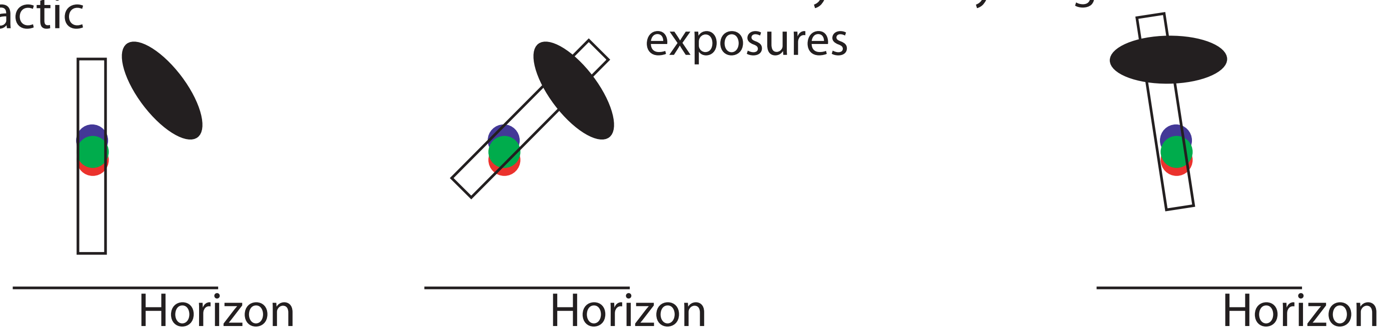
2001−04−21 06:27:07.00

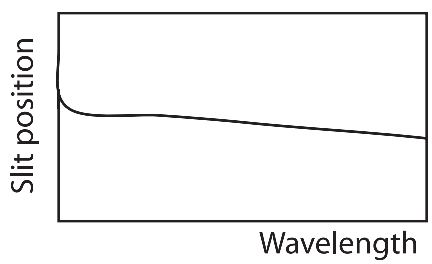
Slit angles

Slit angle for slit spectroscopy - With SN searches we like to align the slit through the host-galaxy core and SN. Generally the parallactic angle is preferred, slit is always perpendicular to the horizon. The supernova can rotate out of the slit!

Parallactic angle

The object rotates in the sky for very long exposures





The position for a color changes with time and smears things out.

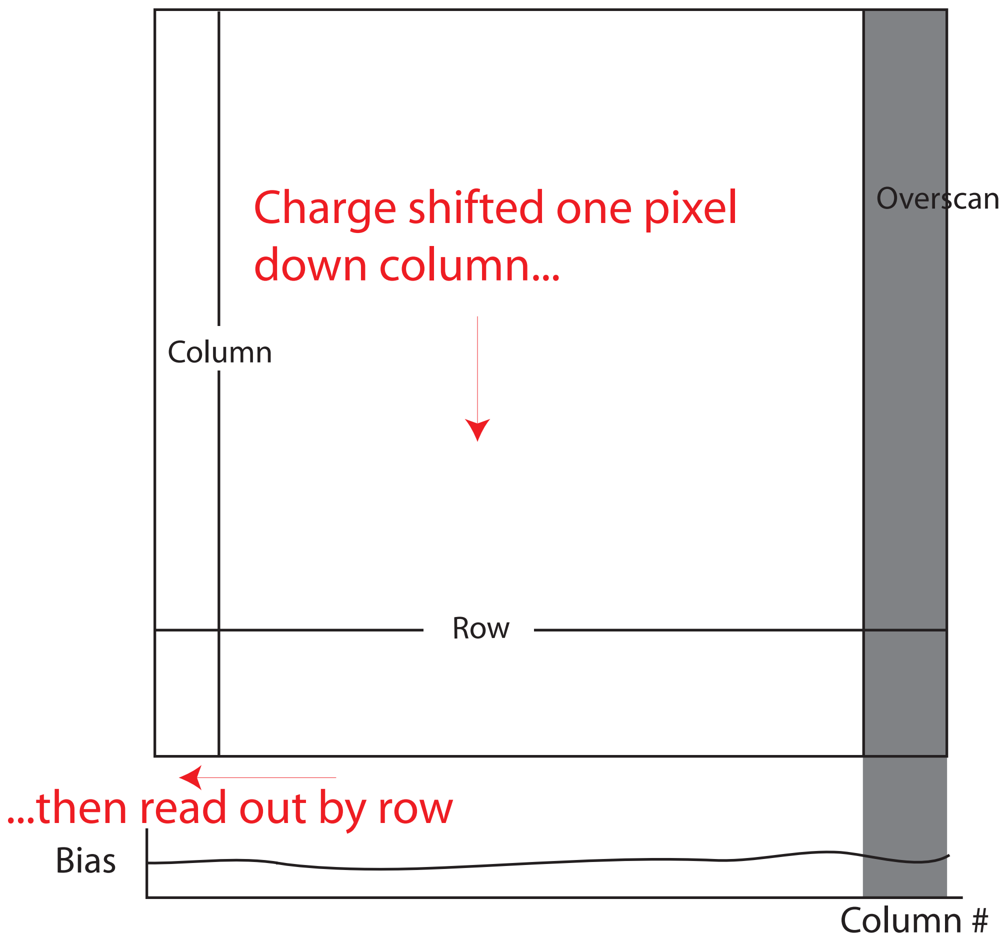
Before Night Observing

Drink lots of juice
No raw seafood before observing
Set watch correctly for new time zone
Make friends with support
Fill dewar
Calibration images - Dome flats, darks, zeros in day time
Linearity test
Green flash

Twilight flats
focus in twilight
pointing when still bright

Calibration Data: CCD

The pixels in the camera need to be normalized with respect to each other.



Additive:

The output signal is "biased" or has a pedestal level that may vary from frame to frame and position over the chip. Average each overscan column, then fit a function a as a function of column. The fit is subtracted from each column of the image.

Residual bias is removed with a Zero frame. Take a set of > 10 images with zero integration. Overscan subtract each. The Zero image pixel has the "mode" value for that pixel from the set. The Zero is subtracted from each image.

Dark current is removed with a Dark frame. Take a set of > 10 images unexposed with the same exposure time planned for real observations. Construct the Dark frame. Generally dark current is low enough that we don't bother with this step. The Dark is subtracted from each image.

Multiplicative:

The relative illumination and QE of each pixel is determined with a "flat field".

Need a source with uniform brightness over the field.

Dome flats - An illuminated screen in the dome. Easy to get but not necessarily the same color as the night sky.
(while doing dome flats may as well do a linearity test)

Twilight flats - The sky when it is faint enough not to saturate the detector but brighter than sources. Not much time to get them. Point telescope east and go from U to I.

Sky flats - The sky from images taken over the night. Polluted with sources.

The Sky is divided from each image.

Result - a cleaned image.

Additional steps:

Fringe removal - in thinned chips, multiple reflections within the chip produce fringe patterns at long wavelengths (R and I bands).

Bad pixel mask.

Arc lamps

Programs to combine and process these data exist e.g. in IRAF

http://iraf.noao.edu

During Observing

Acquire guide star
Examine data as it comes out for many things
- Standard stars for depth
- Pointing in the right place?
- Monitor seeing - observing times
- Monitor focus - out of focus images often have postition dependent PSF
- Sky levels - correct filter

Assess if photometric - affects standard star observations
Monitor weather - wind, temperature of telescope gradient in time affects focus, spatial gradient affects seeing.
Log

Data reduction and transfer

End of night:
Backup
Data reduction